Numerical Assessment of UWB Patch Antenna for Breast Tumor Detection

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***Abstract*—In this paper, numerical assessment of two UWB planar monopole patch antennas is presented. One is disc monopole patch antenna with rectangular-slot, which operates from 2.8 GHz to 11.2 GHz and the second one is rectangular patch antenna, which operates from 3.4 GHz to 14.5 GHz. These antennas perform reasonably well in terms of return loss and radiation efficiency. Radiation patterns are almost omni directional. We propose these antennas for breast tumor detection and location. Microwave Imaging(MWI) systems constructed from UWB patch antennas can be used to construct three-dimensional profiles of the electrical properties of the body part that is being examined. The simulations are performed using CST Microwave studio, an electromagnetic simulator. The simulation results show good agreement with the published results.**

***Index Terms*—UWB patch antenna, Dielectric permittivity and conductivity, Inverse scattering, Microwave imaging, Breast tumor detection.**

I. INTRODUCTION

Cancer has taken a tremendous toll on the society and Breast cancer has become a significant health issue for women [1]. Early diagnosis is currently the best hope of surviving breast cancer. In order to detect breast tumor, there are widespread techniques like X-ray Mammography and Magnetic Resonance Imaging (MRI). However these techniques suffer from some limitations such as their failure to distinguish between benign and malignant tumors. These limitations provide considerable motivation for the development of alternative and/or complementary forms of breast imaging. Microwave Imaging (MWI) system constructed from UWB patch antennas addresses the shortcomings of older techniques. Another rationale for pursuing active microwave imaging is that the breast presents a small volume that is easily accessible, making it a more manageable site for effective imaging than larger anatomical areas [2].

UWB Microwave imaging is a new technology which has potential applications in the field of diagnostic medicine [3, 4]. One of these applications is the detection and location of malignant tissue in woman's breast using an UWB Microwave radar technique [5]. The basis for tumor detection and location is the difference in the electrical properties of normal and malignant breast tissue. Normal breast tissue is largely transparent to microwave radiation while the malignant tissue, containing more water and blood, causes a considerable back scattering of a microwave signal. In UWB Microwave Imaging very low levels of UWB pulses are transmitted from antennas at different locations near the breast surface and the backscattered responses from the breast are recorded, from which the image of the backscattered energy distribution is reconstructed coherently. UWB Microwave Imaging is one of the promising Technologies: it is nonionizing, non invasive, sensitive, specific and low cost.

This technology has witnessed a surge of research work since the declaration of US Federal Communications Commission (FCC) of unlicensed frequency band from 3.1 GHz to 10.6 GHz[6].

This paper proposes two UWB patch antennas, one is disc monopole patch antenna with rectangular-slot and the second one is rectangular patch antenna. Following techniques were used to increase the bandwidth of patch antennas [7-9].

i)Partial ground plane ii)Slots on the patch iii)Steps.

The simulation was performed using CST Microwave studio, an electromagnetic simulator. The simulation results show good agreement with the published results.

II. MATERIALS

Figure 1 shows the geometry of the proposed UWB disc monopole patch antenna (dmpa). The disc monopole has a radius of 7.5 mm, was printed in the front of FR4 substrate of thickness 2mm and a relative permittivity of 4.4. The substrate has a length of 35 mm and the width of 30 mm. Back side of FR4 substrate consists of partial conducting ground plane of dimensions 30 x 15 mm2. Patch antenna has a rectangular slot which was placed y1(y1=0.466 x radius) mm away from the disc center, and whose dimensions are 8x 0.5 mm2.The excitation was launched through a 50 Ω microstrip feed line. Length of feed line was 16 mm and the width was 2mm.Let 'h' be the distance between the feed point of the disc radiator and the ground plane. The proposed UWB rectangular monopole patch antenna (rmpa) is shown in figure 2. A rectangular patch which has a height of 14 mm and a width of 10 mm with a 50 Ω microstrip feed line was printed on the same side of the Teflon substrate of thickness 0.794 mm and relative permittivity 3.34.The width of the microstrip feed line

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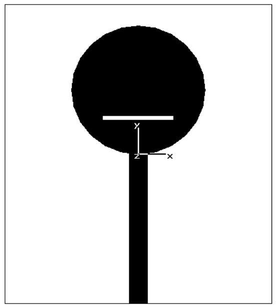
was fixed at 1.5 mm to achieve 50 Ω impedance. On the other side of substrate, the conducting ground plane with a length of 15 mm only covers the section of the microstrip feed line. The height of the feed gap between feed point and ground plane is 1.5 mm. A slot was cut on the partial ground plane with a width of the feed line and a length of LS.



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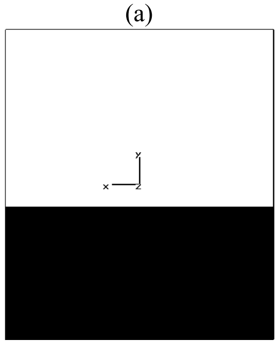

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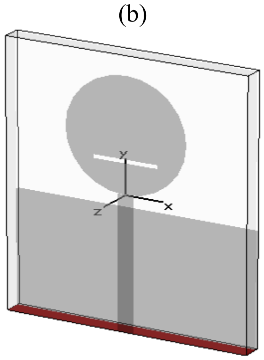
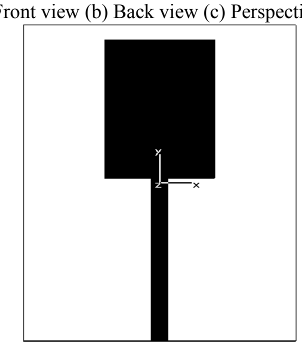


(c)

Figure 1. Model of the printed disc monopole antenna with-rectangular-slot (a) Front view (b) Back view (c) Perspective view



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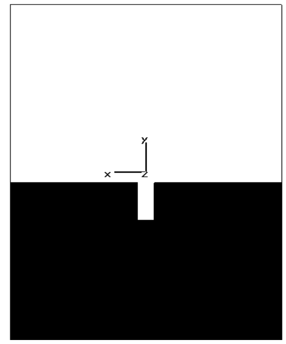

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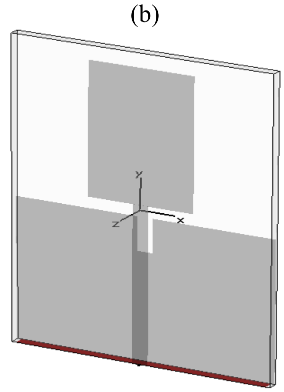

(c)

Figure 2. Model of the printed rectangular monopole antenna (a) Front view (b) Back view (c) Perspective view

III. METHOD

The commercial field simulation tool, CST Microwave Studio [10]... [13], which is based on the Finite Integration technique (FIT) was used to model and simulate UWB planar monopole patch antennas.

The basic parameters used for the simulation are as mentioned below:

The Perfect boundary approximation was used for spatial discretization. The mesh was produced by an automatic mesh generator, which ensures a good compromise between accuracy and simulation time.

Mesh properties used during simulations:

Mesh type: Hexahedral; Lines per wave length: 18; Lower mesh limit: 10; Mesh line ratio: 3 for dmpa / 1.8 for rmpa ; Minimum mesh step: 0.4 for dmpa / 0.62 for rmpa ; Maximum mesh step: 1.25 for dmpa / 1.78 for rmpa for; Mesh nodes: 79596 for dmpa / 21168 for rmpa , an ‘‘add space’’ boundary condition representing the electromagnetic wave propagating towards the outer space was set.

Solver Type: Transient solver with following settings was employed.

Excited discrete port: 1; Excitation duration: 2.538963e-001 ns for dmpa / 2.369699e-001 ns for rmpa ; steady state accuracy limit: -30dB; Maximum number of time steps: 6151 for dmpa / 3516 for rmpa ; Time step width:

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8.254110e-004 ns for dmpa / 1.347888e-003 ns for rmpa; Number of processors used: 01.

A. Tumor Detection Mechanism

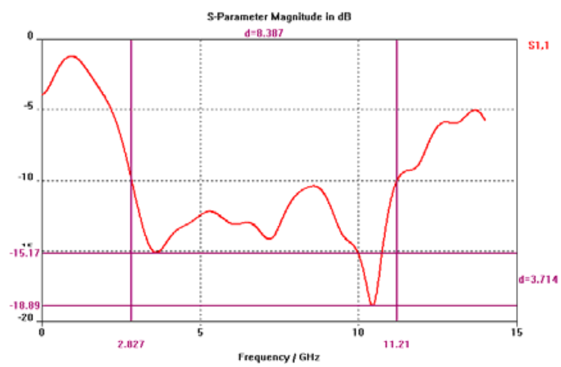
At microwave frequencies, normal and malignant tissues show high contrasts in their electrical properties. Microwave Imaging(MWI)systems can be used to construct three-dimensional profiles of the electrical properties of the body part that is being examined. MWI systems illuminate the body part with electromagnetic radiation. When exposed to microwaves, the high water content of malignant breast tissues cause significant microwave scattering than normal fatty breast tissues that have low water content. It was reported that dielectric permittivity and conductivity increase for cancerous breast tissue is three or more times greater than the host tissue[14].Due to the improved dielectric constant, better tissue characterization too is possible. Using the scattered field at the surface of the body, inverse scattering algorithms reconstruct profiles of the electrical properties of the body.

IV. Results and Analysis

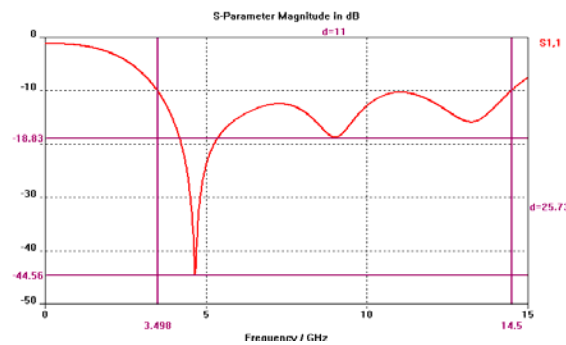
The disc monopole patch antenna was simulated at 4 GHz and 6.5 GHz. The simulated BW from 2.827 GHz to 11.21 GHz (that is 8.387 GHz) was achieved at 10 db return loss. The antenna has return loss of more than 18 db. Antenna resonates at 3.59 GHz, 7.18GHz and 10.45 GHz and exhibits some detuning.

The rectangular monopole patch antenna was simulated at 3.5 GHz, 8.5 GHz and 13.5 GHz. The simulated BW from 3.498 GHz to 14.5 GHz (that is 11 GHz) was achieved at 10 db return loss. The antenna has return loss of more than 40 db. Antenna resonates at 4.67 GHz, 9.01 GHz and 13.25 GHz and exhibits some detuning.

Figure 3 shows the simulated results of return losses for the disc and rectangular monopole patch antennas. From these curves it is clearly seen that we have obtained UWB patch antennas. The radiation patterns of patch antennas under investigation are shown in figure 4 and they are almost omnidirectional. These antennas perform reasonably well in terms of return loss and radiation efficiency. The simulated results are in good agreement with published results [15].



(a)Disc monopole patch antenna



(b) Rectangular monopole patch antenna

Figure 3. Variation of S11 with frequency.

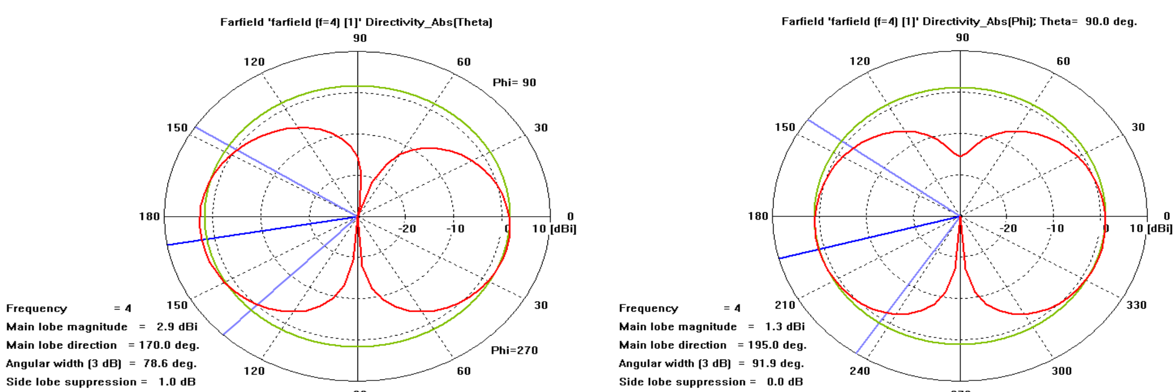


Figure 4(a). Radiation pattern at= 4 GHz in case of disc monopole patch antenna.

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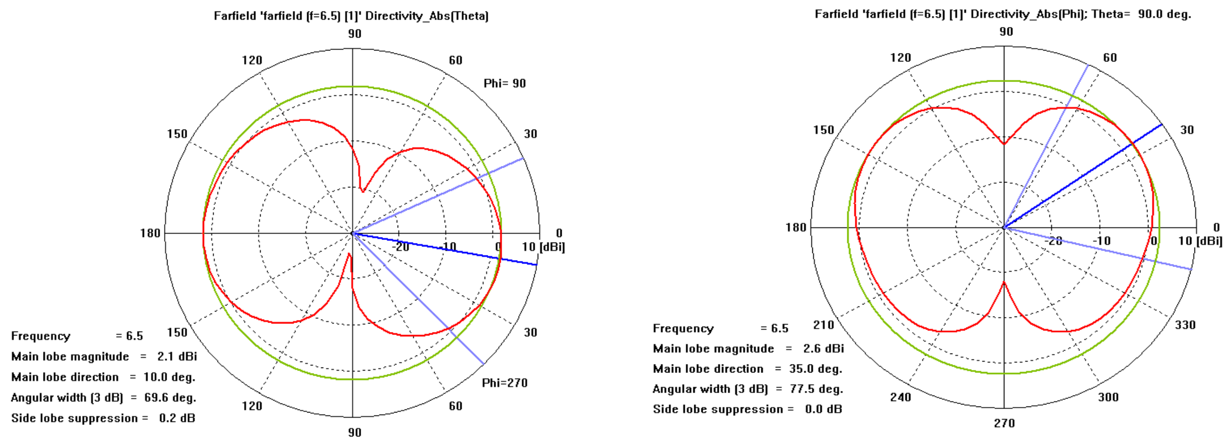

Figure 4(b). Radiation pattern at = 6.5 GHz in case of disc monopole patch antenna

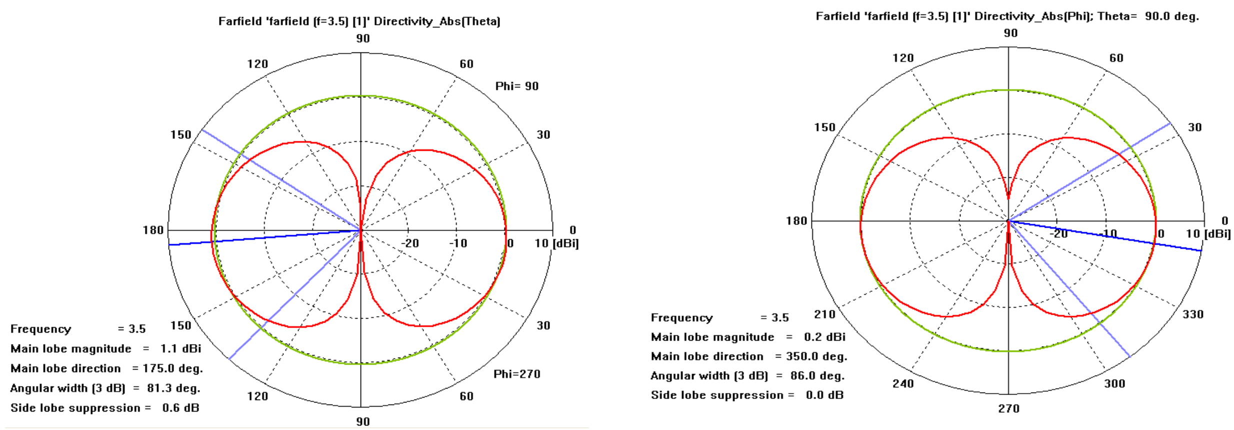

Figure 4(c). Radiation pattern at = 3.5 GHz in case of rectangular monopole patch antenna

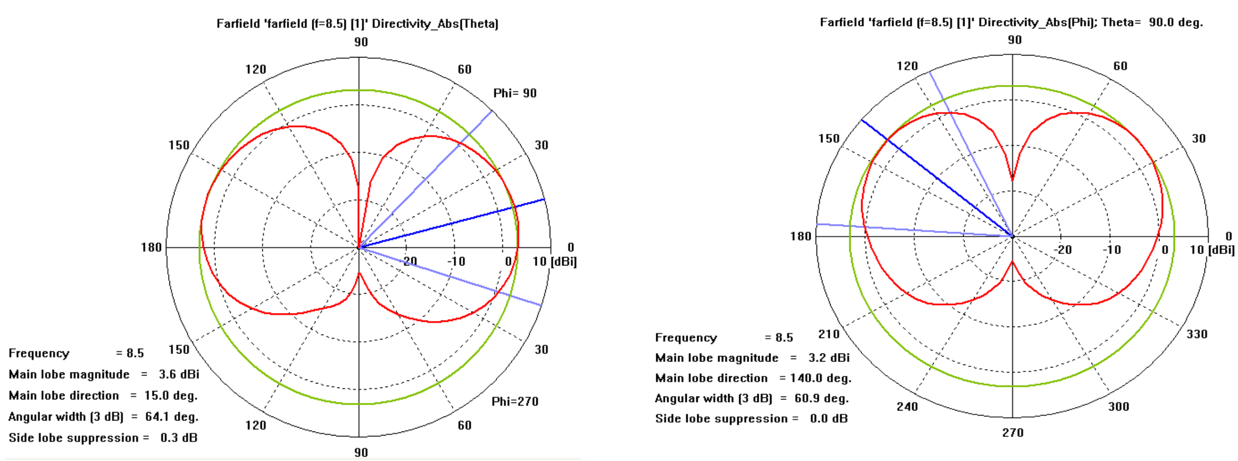

Figure 4(d). Radiation pattern at = 8.5 GHz in case of rectangular monopole patch antenna

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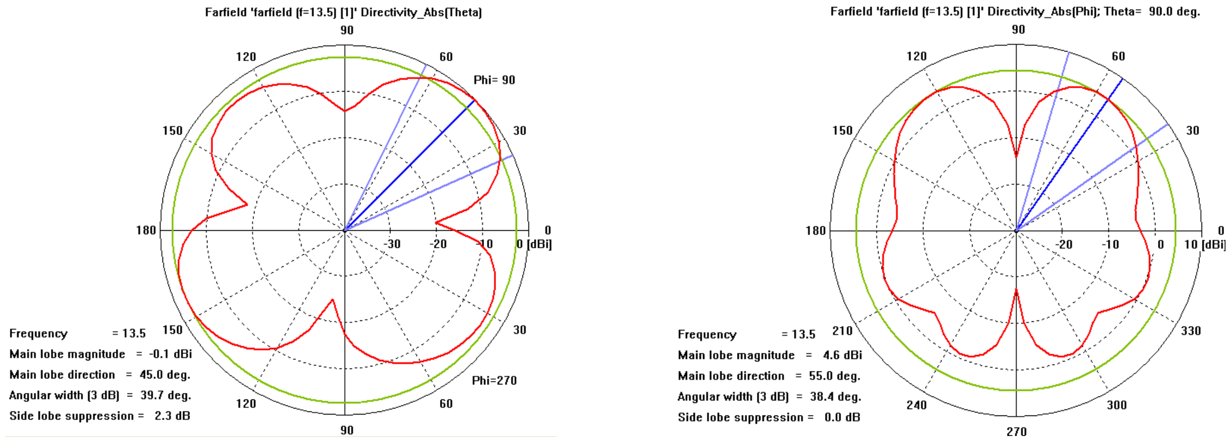

Figure 4(e). Radiation pattern at =13.5 GHz in case of rectangular monopole patch antenna

V. Conclusions

UWB monopole antennas have been successfully modeled and simulated. It is shown that the proposed antennas operate in the UWB. Band width achieved was at 10 db return loss. These antennas performed reasonably well in terms of return loss and radiation efficiency. The radiation patterns of these UWB antennas are nearly omnidirectional over the operating bandwidth. Microwave Imaging (MWI) systems constructed from UWB patch antennas can be used for breast tumor detection, the simulation results obtained by CST microwave studio show good agreement with the published results.

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